ECE 445

Spring 2018

Design Review

Conductive Fabric Gesture-Controlled Sleeve

Team 56

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1 Introduction

1.1 Objective

Bicyclists encounter many distractions as they travel. Between using their arms to indicate turns and navigating, cyclists must also focus their attention on the road to ensure their safety. As the number of riders in big cities has exploded over the years, so have concerns regarding rider safety. In Boston, where ridership has grown by more than 100% since 2007, nearly a third of riders demonstrate distracted bicycling (Wolfe). As a consequence, these safety concerns have created a need for a wearable solution that enables connectivity on the go and optimizes the rider experience, while preventing against the possibility of an accident.

Our goal is to integrate gesture control into a fabric sleeve that can be worn by athletes. This sleeve will be equipped with a capacitive touch sensor system designed on fabric using conductive thread. It will be responsible for detecting simple gestures, which in turn will be routed through an RF module to a receiver capable of performing certain actions depending on the gesture pattern. For the purposes of this project, the external interface will be an LED array setup that will represent the potential use cases of this conductive sleeve technology. As an added (optional) level of complexity, we will also enable this sleeve to control simple functions (i.e. volume control) on a smartphone.

1.2 Background

Efforts to develop applications for smart clothing have thus far been limited. Project Jacquard, a commuter jacket designed by Google and Levi's, is perhaps the closest comparable consumer product to our design. While advertised as keeping bicyclists connected on the move, its rather large ($350) price tag has kept it from finding mainstream adoption. Our sleeve is expected to be a significantly cheaper alternative that maintains a strong degree of functionality and targets a broader set of end users.

1.2 High-Level Requirements List

- The sleeve, located on the arm, will be able to wirelessly communicate with the LED array display. Range of communication will be TBD
- This product will be able to detect four different hand gestures on the sleeve: swipe up, swipe down, single tap, and double tap.
- The sleeve module must weigh less than 100 grams

2 System Design

2.1 Block Diagram

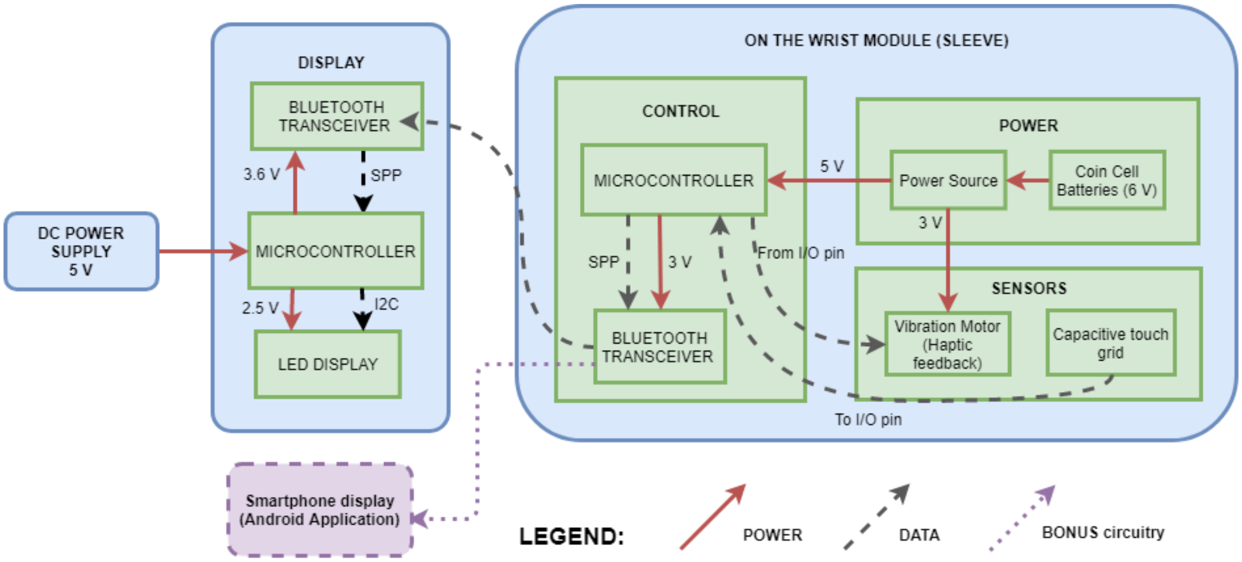

Figure 1. Block diagram overview of system.

2.2 Description of Block

2.2.1 Conductive Thread Capacitive Touch Grid

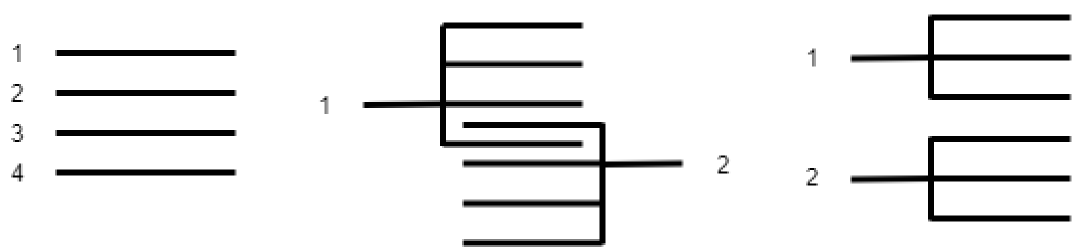

Figure 2. Potential Capacitive Grid Designs

This capacitive touch will be used to detect the gestures made by the biker on the sleeve. It will consist of a conductive thread pattern and will be powered by the microcontroller. It will be capable of detecting four gestures - swipe up, swipe down, single tap and double tap. The capacitive grid will be made of conductive thread weaved into straight lines oblique to sleeve and will be connected directly to the microcontroller.

2.2.2 Microcontrollers

For this project, we have chosen to use the low-cost Atmel MEGA328P microcontroller (MCU) for its simplicity yet ability to support our desired project goals. It supports the generic driver for capacitive touch and has 23 general I/O pins that will be sufficient to communicate all input and output information from the sensors to the Bluetooth module.

There will be two MCUs located on the sleeve and LED demo submodules respectively. The MCU on the sleeve submodule will handle collecting and processing the input from the capacitive touch sensor. It will determine which gesture the user performed and what action should be performed next. Then, it will provide the output signals to the RF transmitter. A second MCU will be used to support the LED display demo. This one will collect the signal from the RF receiver. It will process it to these inputs to determine which LEDs and what color should be displayed, corresponding to the gesture made.

Requirements:

- Must be able to transmit/receive data using programmable UART.
- Must be able to operate in normal mode on 3.0 V input with +/- 15% tolerance.

2.2.3 Bluetooth Module

The Bluetooth module will establish communication between the sleeve module and the LED array display module. Wireless connectivity is important for wearable technology, like this gesture-controlled sleeve, in order to communicate with other devices preserve ease of accessibility for users.

For this project, the HC-05 Bluetooth module has been chosen for its ability to

Sleeve Bluetooth Transmitter

The purpose of the Bluetooth transmitter module is to receive signals sent by the MCU, with both devices mounted on the sleeve module to capture appropriate sensor data.

LED Demo Bluetooth Receiver

The purpose of the Bluetooth receiver module is to pick up on signals sent by the corresponding transmitter module. The receiver will be connected to the demo display. For demo purposes, commands sent through to the Bluetooth receiver will be decoded by the MCU to appropriately control the LED array display.

Requirements:

- Effective range: 0-5m

- Data rate: ~250 kbps
- Receiver sensitivity: -92 dBm
- Voltage: 3.0V +/- 5%
- Successfully pair with receiver and transmitter devices

Verification:

- Monitor Bluetooth serial transmit cycles in code portion of the microcontroller

2.2.4 Vibration Motor

The vibration motor will be used to provide tactile feedback to notify to the user that there is an incoming call. It will be mounted to the sleeve module and its intended location will be the underside of the user's forearm/wrist so as not to be in the way of the capacitive touch grid.

Requirements:

- Vibrations must be felt through the sleeve fabric
- Vibration motors should operate at a voltage range 2.7 - 4.0V

Verification:

- Test the motor at different voltage levels between the operating range as specified on its datasheet, and record the vibration amplitude

2.2.5 LED Array Display

The LED block will be used to demonstrate the sensitivity of the sleeve and the state associated with the gesture pattern. A 2D array of LEDs will model the gesture performed by the user on the capacitive touch grid. For instance, swiping down on the sleeve will prompt the LED matrix to simulate colors travelling downwards, while swiping up will result in colors travelling in the opposite direction. This block will receive its inputs from the second microcontroller that is connected to the RF receiver.

The LED array we intend on using in this lab is a 1.2" Adafruit Bi-Color 8x8 Matrix, equipped with 64 Green and 64 Red LEDs. The 8x8 matrix will also be paired with 2 MAX7219 LED drivers.

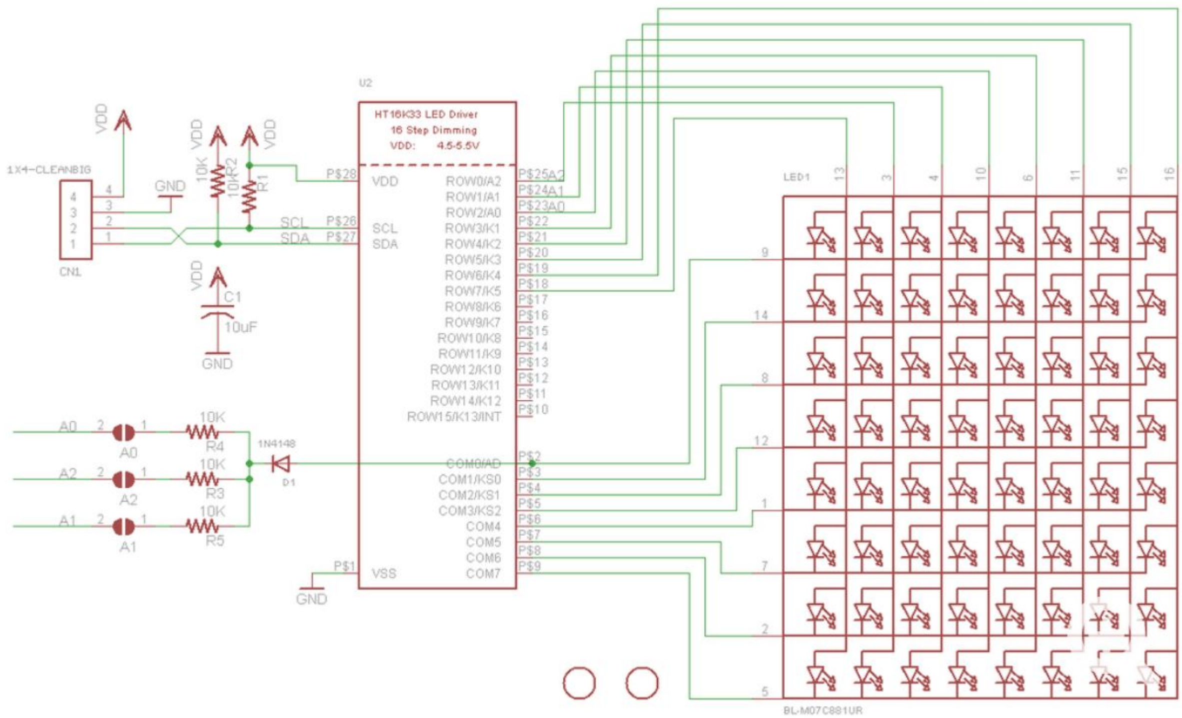

Figure: Circuit schematic for LED array with backpack

The requirements for each device are as listed below:

Requirements

1.2” Bi-Color 8x8 Matrix:

- Operating Voltage: 2.2-2.5 V
- Current: 20 mA
- Will require 2 LED drivers to perform multiplexing operations

Maxim MAX7219 LED Drivers (4 pin SPI Interface):

- Must have a minimum clock period of 100ns
- Will require the use of 2 additional capacitors and 1 resistor to suppress noise and regulate current through the LEDs

Verifications

- Cycle through multiple colors by displaying each upon initialization.
- Be able to effectively interface the two LED drivers with the LED matrix and Arduino
  - Connect pins on drivers to Arduino, perform data transfer and monitor for correct output

2.2.6 Power source

Component	Part No.	Voltage (V)	Typ Current (mA)	Max Current (mA)	Power (mW)	Max Power (mW)
Bluetooth module	NC05	2.8 - 3.8	35	-	105	139.3
Vibration motor		2.0 - 3.6	-	60	120	216
MCU	ATMega328p	3 - 5 V	-	-		
		3	1.7	2.5	5.1	7.5
		5	5.2	9	26	45
LED Array	Adafruit PI:902	2.5		30		75
Max Voltage		5				
Total current				101.5		

* Voltage levels for MCU determine processing speed: 0-10 MHz vs. 0-20 MHz for 3 and 5 V respectively

Power Source components:

- 2x Li-poly batteries (3.7V each)
- 1x Linear voltage regulator for MCU

Requirement: Battery must be able to provide power for xx hours.

Verification: With battery at full charge, apply a load calculated to induce current flow and measure time until current or voltage output decreases by 10%.

Requirement: Physical requirements:

a) Battery size must not exceed standard wrist size
b) Battery weight must not exceed 60% of standard wrist watch weight (~50-90g)

Verification: a) Battery dimensions will be measured using calipers and compared with standard

b) Battery weight will be measured using a digital scale and compared against standard

Requirement: Voltage regulator: Must be able to provide 5V with +/- 10% tolerance.

Verification: Measured using signal generator

Requirement: Voltage regulator: Must be able to provide mA of current at all times

Verification: Measured using signal general with a resistor on breadboard set up

2.2.7 Android Interface

Currently, the Android interface module is expected to be out of scope of the project timeline and will be a stretch goal, as the main demo will be the LED array display. The overall interface of the Android application would be simple and minimal for the purposes of the project. It would primarily consist of a home screen with various options.

All functions would be programmed and implemented with the standard Android Studio and Android SDK and targeted for Android API Level 26 (Oreo 8.0.0).

Requirements:

- Native connectivity to Bluetooth module through Android interface. Must have standard pairing protocols.
- Must run on Android API Level 26 (Oreo 8.0.0).
- Successfully display gesture patterns.

Verification:

- Verify successful pairing to Bluetooth module by monitoring data transfer using serial monitor for microcontroller and app for smartphone.

3 Cost Analysis

Part	Part Number	Unit Cost	Quantity	Total
Conductive Thread	Adafruit Conductive Thread 640	$9.90	1	$9.90
Microcontroller	Atmel ATMEGA328P-PU	$2.20	2	$4.40
Arduino Uno	-	$0 (acquired from previous personal project)	2	$0
Testing Breadboard	-	$0 (acquired from previous coursework)	2	$0
Various MST / Through-Hole Passive Componenets	-	$10.00	-	$10.00
Bluetooth Antennas	DSD TECH HC-05	$9.99	2	$19.98

	Bluetooth Modules			
LED Array	Adafruit Bicolor LED Square Pixel Matrix	$21.40	1	$21.40
Coin Cell Battery	TBD	TBD	TBD	TBD
Vibration Motor	TBD	TBD	TBD	TBD
Total Cost	TBD	TBD	TBD	**TBD**

Table x. Expected component pricing information.

Labor Costs:

2014-2015 B.S. EE from Illinois Salary: $67,000

Hourly Wage = ($67,000 / 1 yr) * (1 yr / 52 weeks) * (1 week / 40 hours) = $32 / hr

Implied labor costs for one group member, assuming 10 weeks left in semester

($32 / 1 hr) * (10 hr / 1 week) * (10 weeks / semester) * (2.5) = $8,000

Total Labor Costs: $24,000

Total Development Costs = Labor Costs + Components Cost (TBD)

= $24,000 + TBD = **TBD**

4 Schedule

ID	Task	Person in Charge	Date Assigned	Deadline	2/12/18	2/19/18	2/26/18	3/5/18	3/12/18
	Sign up for MDR								
2	**Purchase/Acquire Parts**		2/12/18	2/19/18					
	Purchase conductive thread	ALL	2/12/18	2/19/18					
	Purchase insulating material								
	Purchase accelerometer	Guneev	2/12/18	2/19/18					
	Purchase RF transmitter/receiver	Guneev	2/12/18	2/19/18					
	Puchase ATmega238 MCU	Guneev	2/12/18	2/19/18					
	Acquire breadboard	Guneev	2/12/18	2/19/18					
3	**Capacitive Touch / Grid Design**	ALL							
	Dependency: conductive thread testing								
	Sewing conductive thread	Mrunmayi							
	Various pattern testing	Steph							
	Gesture sensitivity threshold testing	Mrunmayi, Guneev							
	Insulating material								
	Waterproofing								
4	**Circuit Simulation**								
	Circuit Schematics								
5	**Component Testing**								
	Additional sensor	Steph							
	Bluetooth transmitter/receiver module	Steph							
	Capacitive grid	Mrunmayi							
	LEDs	Guneev							
6	**Module Testing**								
	LED array	Guneev							
	Power (voltage regulators)	Mrunmayi							
7	**PCB Design: 1st Round**	Guneev							
	Design								
	Order								

ID	Task	Person in Charge	Date Assigned	Deadline	3/26/18	4/2/18	4/9/18	4/16/18	4/23/18	4/30/18	5/7/18
8	**PCB Design: Final Round**	Guneev									
	Design Revisions										
	Order										
9	**Mock Demo / Final Deadlines**		4/16/18	4/20/18							
	Demonstration Sign-Ups	ALL	4/16/18	4/20/18							
	Mock Presentation Sign-Ups	ALL	4/18/18	4/24/18							
	Final Presentation Sign-Ups	ALL	4/23/18	4/27/18							
	Final Paper Due	ALL	4/23/18	5/2/18							

Table x. Progress schedule split by team member.

5 Risk Analysis

We believe the biggest risk of our project will be the sensors block. Our design depends on the sensitivity of the capacitive touch sensor to provide accurate information to the microcontroller. Information from the touch will be input signals to the microcontroller to determine the action that should be performed next. In particular, one design challenge for the touch sensor will be to determine the adequate levels of gesture sensitivity. Different users will make swiping or tapping gestures at varying rates, so to avoid false positives, thorough testing must be performed to achieve the optimal pattern design and gesture tolerances.

As a result, our project will also be dependent on the microcontroller's clock speed. For both sensors, we will need to be mindful that they are not too sensitive, otherwise the system will perform actions when they are not needed. If they are not sensitive enough, the system will not receive enough data. Another challenge will be implementing low-level code for bluetooth module driver.

6 Ethics & Safety

As we continue to work towards finalizing the design of our sleeve, we hope to eliminate the possibility of any electric shock to a potential rider. Given that the bicyclist is interfacing directly with conductive fabric and is also wearing the sleeve, we want to ensure that we incorporate some type of electrical insulating fabric to avoid direct skin to sleeve contact and afford the rider greater protection. One of the ways we hope to minimize this risk and also protect the sleeve from the environment is by applying a water resistant epoxy. While this is a later-stage design consideration, if pursued, we would need to consider the impact of the epoxy on the sensitivity of the conductive thread and ensure that the overall performance of the sleeve is not compromised.

7 References

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Keim, Robert. "Circuits and Techniques for Implementing Capacitive Touch Sensing." *All About Circuits*, 30 May 2016, www.allaboutcircuits.com/technical-articles/circuits-and-techniques-for-implementing-capacitive-touch-sensing/.

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